

Some experiments with sound absorption ceramic materials

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Abstract. Several different methods are used to lower air pressure periodical variations. This phenomenon is in audio bandwidth named sound absorption (SA). Different materials are for this purpose used and an interesting possibility is here tested and explained.

We prepared different ceramic specimen and tested their behavior in an impedance Kundt tube in order to understand their specific SA properties.

SA theoretic background, other SA materials, ceramic materials (CM) preparation and CM SA proper capabilities experiments are here presented.

1 Introduction

In 1848 Irish physic and engineer William Thomson, best known as Lord Kelvin defined an absolute temperature and energy theory, point and law for an absolute 0, indicated as K [1]. Vibration is at the basis of energy as atoms and molecules act and interact through them. From an audible point of view, the normally accepted 20-20kHz bandwidth has a physical even behaviour, but, due to the fact that human hearing system behaves differently for different low, middle and high sub-bandwidths, it is sometimes necessary to adapt free sound behavior, especially in enclosed spaces, in order to make sound and audible messages more understandable for listeners.

Depending on specific room acoustics, it is sometimes necessary to focus sound energy in specific listening areas and / or deflect sound energy to improve intelligibility. Another possibility is to diminish sound energy and time propagation lowering its dispersion path through specific sound absorbing materials. Very common ones are textile curtains, as used in opera theatres [2], resonating boards, as used in chamber music rooms [2] and Helmholtz resonators as normally used to correct specific low frequency unpleasanties in dancing facilities [2]. The last principle will be applied to our work.

2 Problem and possible solution

Conventionally perceived sound can be roughly divided in a first direct part and a subsequent so called tail, due to all the complex reflection paths from enclosing surfaces and enclosed objects, as first mathematically expressed by W. C. Sabine in 1898 [3]. Human sound perception tends to integrate first 20 ms energy and information in order to determine listener's 3D position

inside the space and to increase intelligibility as explained in [2]. Later arrivals tend to be integrated in a so called sound tail component, mainly present at medium and low frequencies, as high frequencies tend to be well absorbed by textile and human components present in the room [3]. Larger spaces acoustic modification becomes then a complex task. In particular places such as old churches or historical palaces the walls cannot be covered with whatever sound absorbing panels or curtains for aesthetic, historical or architectural reasons. We explore here the possibility to partially or maybe completely cover needed surfaces with equal or maybe differently perforated ceramic panels using the Helmholtz resonators low frequencies principle [4] for sound absorption. In order to preserve room aesthetics, inner surfaces may be coated with eventually coloured and enamelled ceramic panels, suitably perforated, in order to obtain sound absorption at needed frequencies.

In our experiment we mainly focus on human voice fundamental frequencies [4] SA, i.e. between 100 Hz and 1 kHz in order to obtain sound absorption to improve speech intelligibility.

3 Materials and methods

9 x 100 mm circular ceramic material samples have been artisanally prepared after clay 5 days drying and subsequent long firing at 1000° C.

4 x 6 mm, 2 x 20 mm, 2 x 25 mm, and 1 x 30 mm thick discs were manually drilled with 2 mm, 3 mm, 5 mm and 6 mm diameter regularly disposed holes respectively, as shown in Table 1 and in Figure 1.

Specimen n.	Thickness mm	Hole dimension mm	Perforation %
1	6	2	3,5
2	6	3	8
3	6	6	32
4	6	2	2
5	20	2	4
6	20	2	3
7	25	6	50
8	25	3	11
9	30	5	25

Table 1 Specimen main characteristics

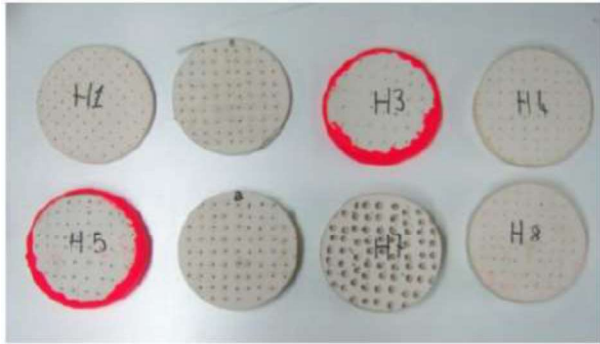


Figure 1: 9 x specimen

The SA coefficient measurement at normal incidence was performed in accordance with UNI EN ISO 10534-2 “Determination of the sound absorption coefficient and the acoustic impedance in impedance tubes - Transfer function method” [5]. A 100 mm inner diameter 560 mm long Kundt impedance tube at normal incidence with 50 mm microphone distance was used as shown in Figure 2

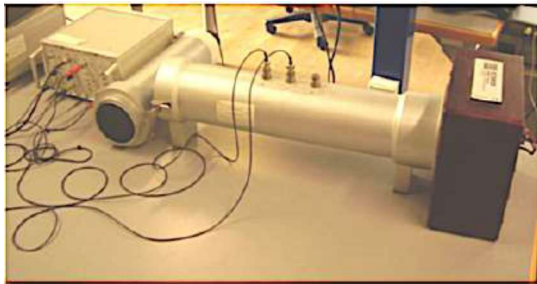


Figure 2: Kundt tube for normal incidence SA measurements

Each specimen was placed at 50 mm, 100 mm, 150 mm, 200 mm and 250 mm respectively, in order to leave an air cavity or gap behind, up to a rigid surface.



Figure 3: Ceramic specimen inside the Kundt tube sample holder

Due to the Kundt tube physical dimensions and the measuring microphones placement, the normal incidence absorption coefficient value is valid in the frequency range between 100 Hz - 2 kHz [6].

The following 9 Figures show the specimen SA in 1/3 octave frequency bands depending on the air gap behind.

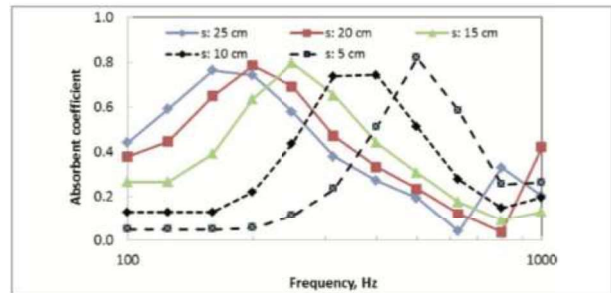


Figure 4: Specimen 1 (thickness 6 mm, holes 2 mm, perforation 3,5 %) SA trend on air gap depth variation

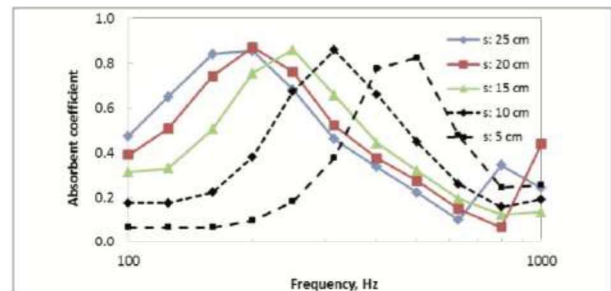


Figure 5: Specimen 2 (thickness 6 mm, holes 3 mm, perforation 8 %) SA trend on air gap depth variation

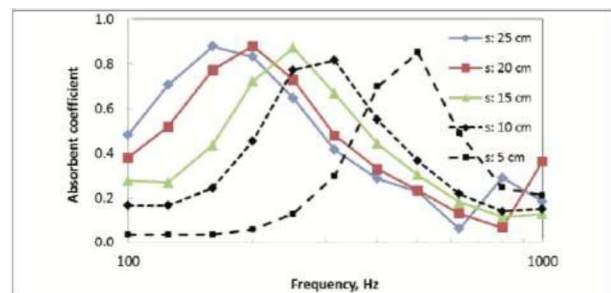


Figure 6: Specimen 3 (thickness 6 mm, holes 6 mm, perforation 32 %) SA trend on air gap depth variation

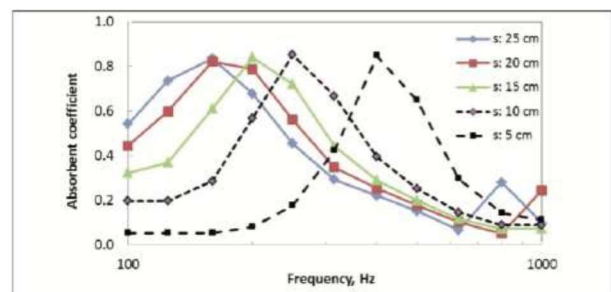


Figure 7: Specimen 4 (thickness 6 mm, holes 2 mm, perforation 2 %) SA trend on air gap depth variation

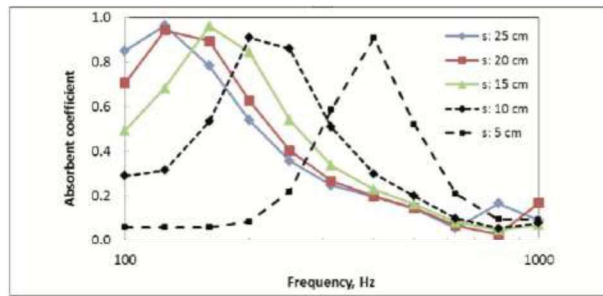


Figure 8: Specimen 5 (thickness 20 mm, holes 2 mm, perforation 4 %) SA trend on air gap depth variation

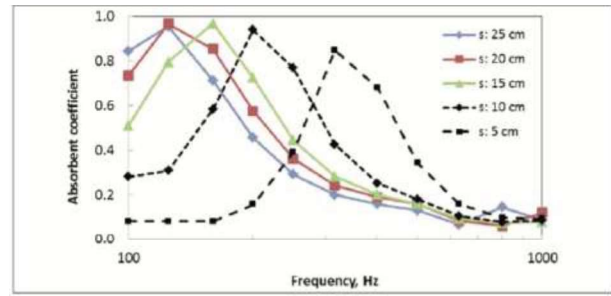


Figure 12: Specimen 9 (thickness 30 mm, holes 5 mm, perforation 25 %) SA trend on air gap depth variation

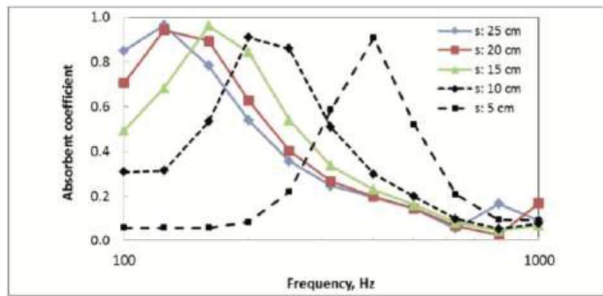


Figure 9: Specimen 6 (thickness 20 mm, holes 2 mm, perforation 3 %) SA trend on air gap depth variation

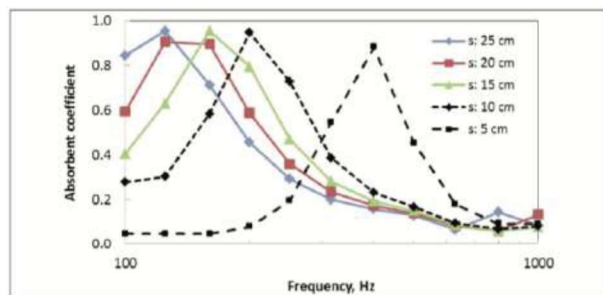


Figure 10: Specimen 7 (thickness 25 mm, holes 6 mm, perforation 50 %) SA trend on air gap depth variation

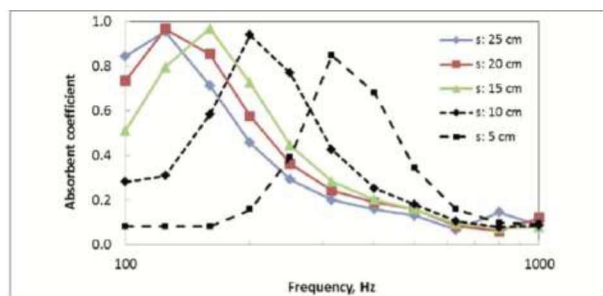


Figure 11: Specimen 8 (thickness 25 mm, holes 3 mm, perforation 11 %) SA trend on air gap depth variation

4 Results and discussion

Perforated plates sound absorption is based on Helmholtz acoustic resonators principle; it is well established that this SA system is limited in just a narrow sound bandwidth so we enlarged their absorption frequency band mounting them at a specific distance from a rigid surface behind them.

As hypothesized, the absorption coefficient peak of each specimen shifts towards higher frequencies as the cavity length between the specimen and the rigid wall behind decreases [7], [8], [9].

The possible applications of sound-absorbing materials made with ceramics can derive from aesthetic, architectural or practical needs, as colored and glazed ceramics take on a pleasant appearance and their cost/m² is very low in comparison with curtains and other absorbing materials. Their use in a cultural ambitus as churches and theatres can strongly contribute to mid frequency SA and their correct placement can raise unwanted echoes in specific frequency bandwidths, where traditional porous textiles or plastic derived materials are aesthetically poor or inefficient.

The right perforated ceramic tile selection depends on the specific frequency range; the correct combination of thickness, holes diameter and air gap depth allows to achieve optimal acoustic absorption in the aimed frequency area.

A first limitation of the present work is the sound only normal incidence measurement, which does not take into account other incidence angles, instead of a diffuse incidence in reverberation chambers, closest to real SA conditions in room acoustics.

A second limitation is the small discs SA surfaces handcraft made, which may have influenced in somehow the measurement results.

In any case, the overall tendency is clear and strongly confirms the experiment validity and the obtained results.

5 Future work

We plan to introduce our ceramic plates in an Italian church sound correction phase in order to confirm *in vivo* ceramic perforated tiles SA capabilities.

A possible promising development is its use in high temperatures environments (e.g. boiler rooms), where normal SA materials can not be utilized.

Despite ceramic materials fragility, as they can not withstand sudden impacts, we see great opportunities in SA management because they are waterproof and cleanable, they present poor thermal and electrical conductivity, are resistant to scratches and rubbing, resist to high temperatures and resist to compression.

6 Literature

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